Grasping of Deformable Objects Applied to Organic Produce

Alon Ohev-Zion and Amir Shapiro

Department of Mechanical Engineering
Ben-Gurion University of the Negev Bee'r-Sheva, ISRAEL.
{alonohev, ashapiro} bgu.ac.il

Keywords: grasping, deformable compliant object, grasp optimization.

Grasping mechanisms (*grippers*) are used for a wide range of applications including fixturing arrangements, industrial, agricultural, and service robotics for medical and home use. The gripper must immobilize the object it is manipulating, while applying the minimal necessary grasping force, in order to prevent the grasped object's bruising. Performing grasp analysis and synthesis, requires the development of a grasp model.

The grasp model includes kinematic, dynamic and contact models, where the last define the coupling between the contact forces and their deformations [4]. All grasp models greatly depend on the system's parameters, such as the number of contact points, the object's geometry, the gripper's structure, the desired object's manipulation, and the mechanical properties of the object and gripper [3].

Contact models were developed in order to assess and predict the reaction forces and local deformations. They vary from considering rigid components and sharp fingertips with no friction at the contact point, to soft finger models – assuming compliant components, which imply a contact area with a force and torque distribution [1,5]. Note that the contact's location is referred as a *contact point*, although geometrically it is a *contact patch* in some of the discussed compliant contact models.

The goal of this work is to provide the set of grasp forces and torques that can be applied to an object, without losing equilibrium and stability constraints. The grasp planner, provides an optimal set of positions for n contact points, which are optimal in the sense of minimizing contact force and torque at each contact point. The planning is independent in the selection of a specific gripper, as oppose to more traditional techniques [2]. Under the constraints of maintaining grasp's stability and not bruising the object, two grasp – quality criteria are currently in consideration: 1) The minimal required grasping force and torque. 2) The maximal allowed grasping force and torque.

In order to achieve this goal, the following assumptions and definitions are made: consider a virtual gripper, whose n hemisphere fingertips can be positioned at every point in space, and actuated at any desired direction. The fingertips and the object are considered as compliant (quasi-rigid) [1,6]. The object's B geometry and mechanical properties are known, and it may be subjected to a known set of external forces and torques (*loads*) $\tilde{F}$. The object can be grasped

by a set of grasp configurations $\tilde{K}$, where each configuration is defined by the locations of the n contact points on B's circumference.

The optimal grasp – planing objective is described by (1), and as follows: Given an object B, grasped by n contact points positioned on its circumference in a specific locations – that is a "grasp configuration", loaded by a specific external load in $\tilde{F}$, search B's circumference for an optimal grasp – quality measure. The search is comprise two stages. First, evaluate a grasp – quality measure for the current grasp configuration, which is follows by the evaluation of a grasp – quality measure for the current grasp configuration, for all loads in $\tilde{F}$. This algorithm can be analytically described as,

$$\text{Optimal Grasp Configuration} = \arg\min_{\tilde{\mathbf{K}}} \left(\min_{\tilde{\mathbf{F}}} \left(\mathbf{J}\left(\tilde{\mathbf{F}}\right)\right)\right), \tag{1}$$

where J is the grasp – quality evaluation function.

The search is performed in the eight dimensional space, whose parameters are the object's surface geometry coordinates (two), the applied external spatial forces vectors (three) and torques (three). The algorithm output is the locations of the n contact points on the object's circumference that defines the optimal grasp configuration, in the sense of the the grasp quality criterion.

Currently, a virtual environment that enables simulation of the object's dynamics under the integrated contact model is constructed. Both non – linear contact models by Elata [1] and Xydas's [6] are studied for their properties and differences. An experimental system is being built, in order to validate the grasp's analysis and synthesis.

Acknowledgement

Supported by the European Commission in the 7^{th} Framework Programme (CROPS GA no 246252)

References

1. D. Elata and J. G. Berryman. Contact force-displacement laws and the mechanical behavior of random packs of identical spheres. *Journal of Mechanics of Materials*, 24(3):229–240, 1996.
2. C. Goldfeder, P. Allen, C. Lackner, and R. Pelossof. Grasp planning via decomposition trees. In *Proceedings of the International Conference on Robotics and Automation. IEEE*, pages 4679–4684, 2007.
3. A. Miller and P. Allen. Graspit! a versatile simulator for robotic grasping. *Robotics Automation Magazine, IEEE*, 11(4):110–122, 2004.
4. A. Shapiro, E. Rimon, and J. Burdick. On the mechanics of natural compliance in frictional contacts and its effect on grasp stiffness and stability. In *Proceedings of the International Conference on Robotics and Automation. IEEE*, volume 2, pages 1264–1269, 26-may 1, 2004.
5. C. Xiong, M. Wang, Y. Tang, and Y. Xiong. Compliant grasping with passive forces. *Journal of Robotic Systems*, 22(5):271–285, 2005.
6. N. Xydas and I. Kao. Modeling of contact mechanics and friction limit surfaces for soft fingers in robotics, with experimental results. *The International Journal of Robotics Research*, 18(8):941–950, 1999.